^{131}Cs myocardial scintigraphy

Application to assessment of anterior myocardial infarction

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Earlier studies have indicated that caesium-131 is a good myocardial scanning agent for the demonstration of anterior infarcts. One hundred and ten patients with documented anterior myocardial infarction were studied by ^{131}Cs myocardial scintigraphy. An anterior area of decreased uptake of caesium was noted in all but 3 subjects whose necrotic zone was likely to be of small dimensions. In 20 cases, the scintigram showed a definite, sometimes very large, cold area whereas the electrocardiogram failed to display any diagnostic feature of myocardial necrosis. In most of the latter instances, the electrocardiographic diagnosis was obscured by the presence of intraventricular conduction disturbances.

In order to visualize the intracardiac cavities, the ^{131}Cs investigation was usually completed by a ^{113m}In scintigram, which allowed recognition of a parietal aneurysm in 12 of the 18 patients with extensive anterior lesions.

In each case, an index of necrosis was computed from planimetric measurements of the infarcted area as compared to the total left ventricular surface in both the anteroposterior and left anterior oblique projections. This index was shown to correlate with the incidence of major complications developing after the acute episode of coronary occlusion.

The sensitivity, specificity, and accuracy of the method are briefly discussed. It is felt that myocardial scintigraphy represents a sound approach to the semiquantitative assessment of anterior myocardial infarction; the clinical usefulness of the technique seems sufficiently demonstrated to prompt further research in this field.

Earlier studies, carried out in this laboratory as well as in several others (Carr et al., 1964; Himes, Worth, and Smith, 1965; McGeehan, Rodriguez-Antunez, and Lewis, 1968; Planiol et al., 1971; Brochier et al., 1972; Burguet and Merchie, 1972), have indicated that the significant selective myocardial uptake of potassium and its analogues makes it possible to perform myocardial scintigrams, using salts of caesium-131. The uptake of caesium is considerably reduced in infarcted segments, to about 15 per cent of normal (Carr et al., 1973). These characteristics have led to the use of ^{131}Cs as an imaging agent for myocardial infarction. However, the principal emission of ^{131}Cs is a low energy 29.4 keV x-ray; its high absorption in tissues means that this radionuclide does not lead to reliable investigation of the posterior aspect of the heart. None the less, it seems particularly suitable for the assessment of anterior infarction.

The purpose of the present paper is to describe our experience of ^{131}Cs myocardial scintigraphy, in 110 cases of anterior myocardial infarction. These cases were selected from 565 myocardial scintigrams performed to date in our laboratory. The clinical usefulness of the technique will be outlined and its interest for the semiquantitative evaluation of anterior necrotic lesions will be stressed.

Subjects and methods

One hundred and ten subjects with documented anterior myocardial infarction were investigated. Two of the following three criteria were considered necessary to make a firm diagnosis of myocardial infarction: 1) typical clinical history; 2) characteristic electrocardiographic abnormalities; 3) typical serum enzyme increases at the time of the acute episode.

The study group comprised 100 men and 10 women, ranging in age from 26 to 87 years, with an average of 55.

The scintigram was performed between 2 days and 18 years after the acute episode, using a technique
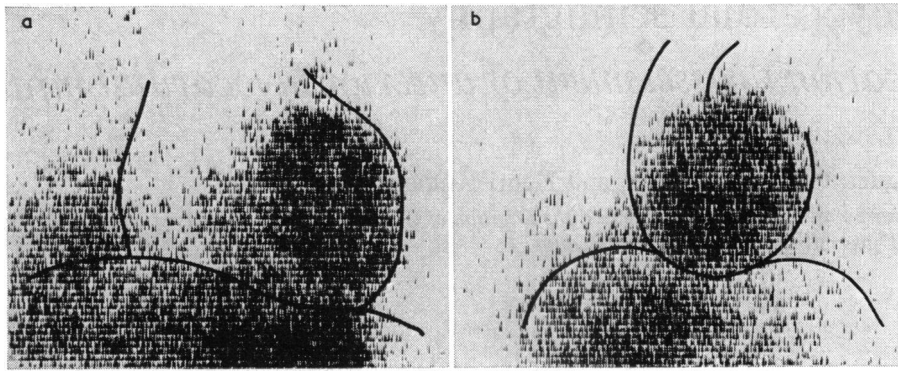
FIG. 1 *Normal* ^{131}*Cs scintigram in the anteroposterior (a) and left anterior oblique (b) projections. The cardio-aortic silhouette is grossly drawn from comparison with the chest x-ray. The balloon-shaped left ventricle lies on top of the hepatic dome. The medial zone of the anteroposterior view corresponds to the right atrium. The activity is very low in this area because of the interposition of the sternum and the thinness of the atrial muscular tissue.*
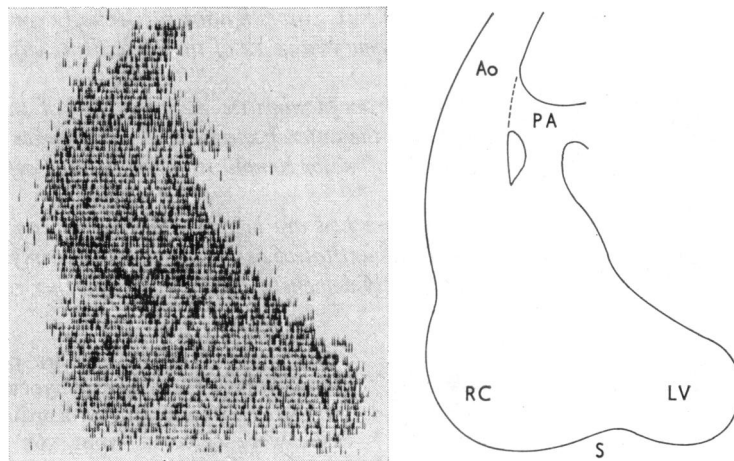

FIG. 2 *Normal picture obtained by* ^{113m}*In scintigraphy. Here, the intracardiac cavities and large vessels are visualized. Ao, aorta; LV, left ventricular cavity; PA, pulmonary artery; RC, right cavities; S, indentation at the level of the septum.*

previously described in detail (Burguet and Merchie, 1972). A dose of 25 μCi ^{131}Cs (Cs Cl) per kg body weight was injected intravenously. Ninety minutes after the injection, the myocardial scintigram was recorded in both the anteroposterior and left anterior oblique projections. A scanner (Picker magna-scanner 500) with a 12.7 cm crystal and a 55 holes collimator (2114 B) for low energies with 7.6 cm focal distance was used. The scanning speed ranged from 35 to 60 cm per minute.

An example of the normal pictures obtained in these conditions is shown in Fig. 1. The left ventricular myocardium is the only structure to be clearly visualized; because of the preponderant mass of the left ventricle, the atria, right ventricle, and surrounding extracardiac tissues do not contribute significantly to the image. In spite of the contractile movements of the heart, the external boundaries of the left ventricle are satisfactorily delineated.

In most instances, to visualize the intracardiac cavities, a second scintigram was performed 5 minutes after an intravenous injection of 3 mCi of another radionuclide, indium-113 m. The procedure followed for the preparation of the solution of this radionuclide has also been previously described (Radermecker *et al.*, 1970). ^{113m}In
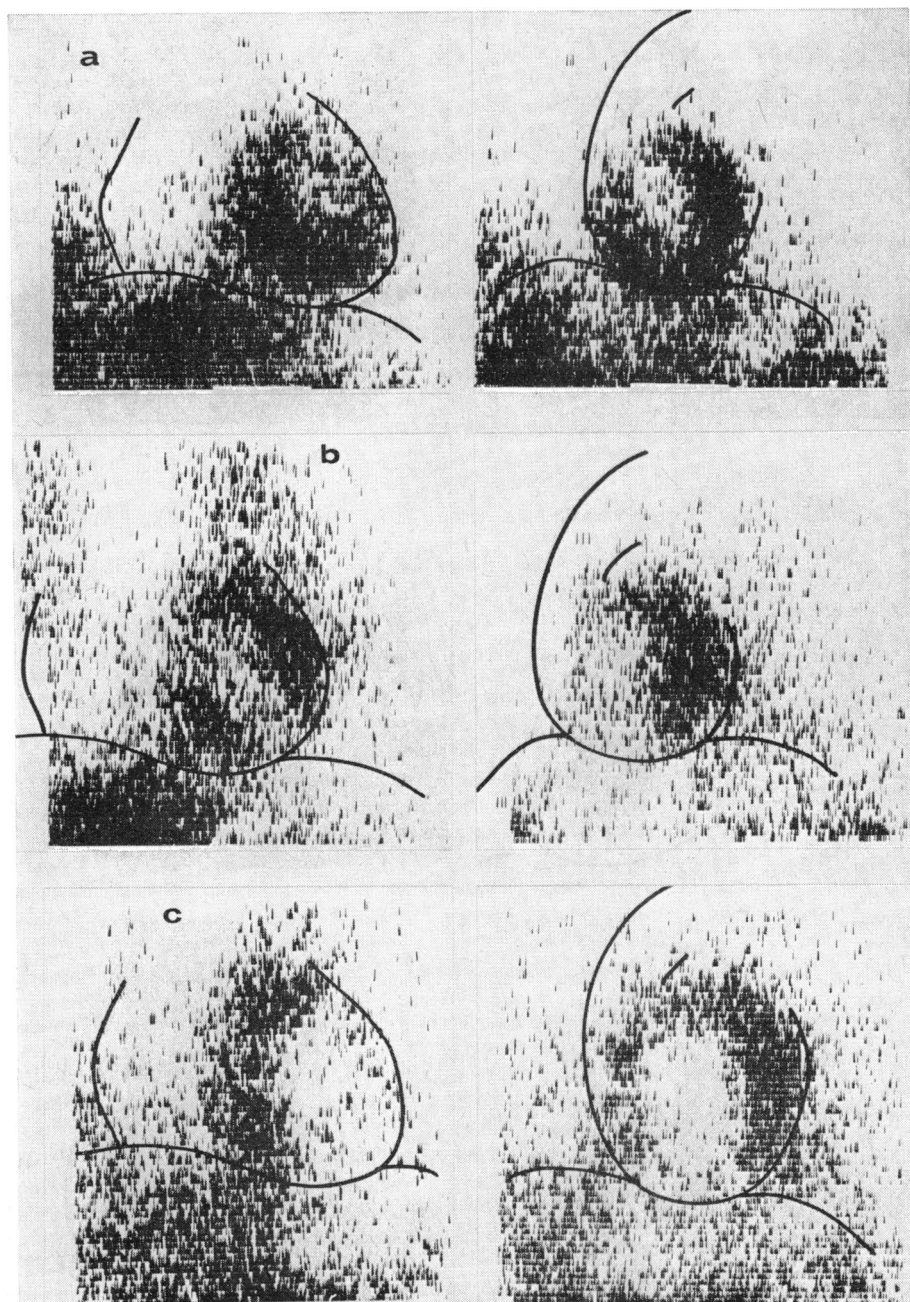
FIG. 3   *Three examples of anterior infarcts visualized by* ^{131}Cs *scintigraphy. To the left anteroposterior projection; to the right left anterior oblique projection: a) high lateral infarc- b) anteroapical infarct; c) extensive anterior infarct.*
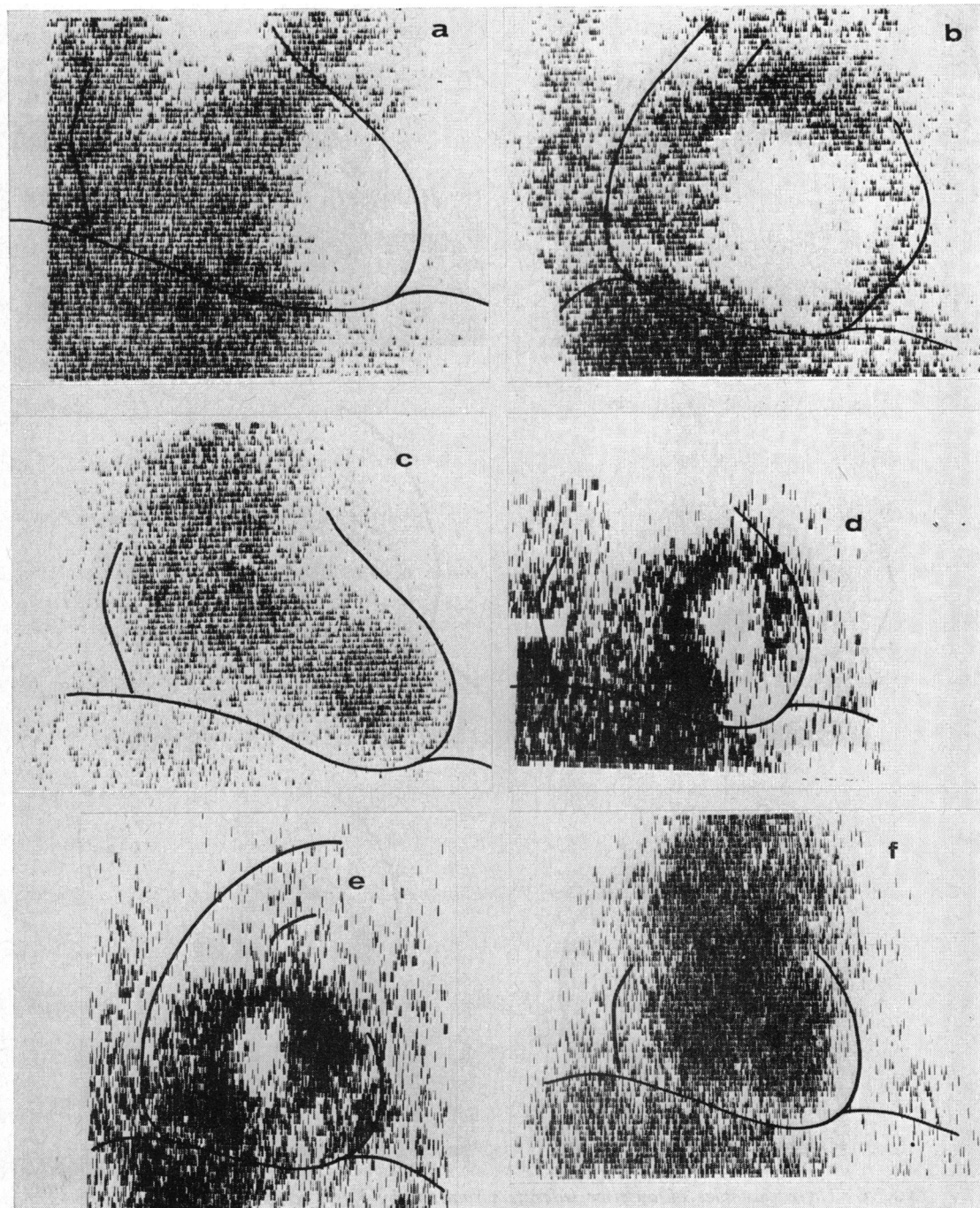
which is quickly complexed to transferrin and, to a lesser extent, to α_2-globulins (Hosain *et al.*, 1969), can be used in scintigraphy, to demonstrate the intracavitary blood mass. An example of the normal image of ^{113m}In scintigram is shown in Fig. 2.

Results

Of the 110 scintigrams, 107 showed a clearcut cold area of decreased uptake on the anterior aspect of the heart. Depending upon the exact location and extent of the cold area, the cases were classified into strictly anterior (15 cases), lateral (28 cases), high lateral (21 cases), anteroapical (25 cases), and extensive anterior (18 cases) infarcts (Fig. 3).

Eleven patients underwent two successive ^{131}Cs myocardial scintigrams, with an interval varying between 18 days and 24 months. With the exception of 1 patient who had developed severe cardiac failure, the scintigraphic images remain unchanged from one investigation to the other: the area and the shape of the defect failed to show any significant variation.

In 12 patients whose ^{131}Cs scintigram had revealed an extensive anterior lesion, the ^{113m}In image showed an abnormal contour of the left ventricular cavity with unusual asymmetric elongation, dilatation, or bulging. The superposition of the ^{113m}In picture on the ^{131}Cs scintigram allowed the diagnosis of parietal aneurysm to be made (Fig. 4).

The comparison between the standard electrocardiographic features and the results of the scintigrams deserves some comment. Out of the 110 cases, only 3 had an entirely normal ^{131}Cs scintigram. It is worth noting, however, that in these 3 patients the electrocardiogram showed a typical Q wave in only one single right praecordial lead (V1 or V2) and that the necrotic zone might reasonably be assumed to be of small dimensions.

In contrast, in 20 patients, the scintigram showed a definite, sometimes very large, cold area, whereas the electrocardiogram failed to display any diagnostic feature of myocardial infarction. In these cases, the diagnosis could only be made on the basis of the clinical history and biochemical data. Among these 20 patients, 2 had complete left bundle-

TABLE *Correlation between index of necrosis and number of pathological Q waves in leads I, aVL, V2, V3, V4, V5, or V6*

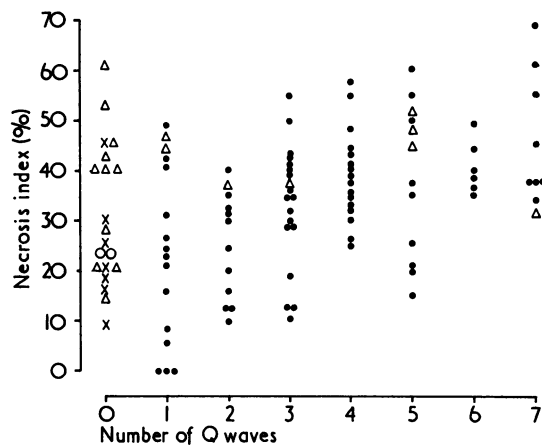| Number of pathological Q waves	Mean index of necrosis (%)
0	14.6
1	24.8
2	26.5
3	34.3
4	38.8
5	36.2
6	37.8
7	41.6

$F = 9.88$; $P < 0.001$

FIG. 5 *Relation between the total number of pathological Q waves seen in leads I, aVL, V2, V3, V4, V5, or V6 of the standard electrocardiogram and the index of necrosis.* ● *Cases with typical electrocardiographic tracing of anterior infarction;* × *cases with normal electrocardiogram, signs of left ventricular hypertrophy, or isolated left anterior hemiblock;* △ *cases with severe non-specific intraventricular conduction disturbances (QRS duration ⩾ 120 ms);* ○ *cases with typical complete left bundle-branch block.*

FIG. 4 *This figure illustrates a case of parietal aneurysm in a patient aged 63 with extensive anterior myocardial infarction. Because of progressive development of cardiac failure, this aneurysm had to be surgically removed 6 months after the acute episode of coronary occlusion. The preoperative anteroposterior (a) and left anterior oblique (b) ^{131}Cs scintigrams show the dilated heart and the extensive anterolateroapical defect; (c) the corresponding ^{113m}In scintigram where the apical portion of the unusually large left ventricular cavity represents the aneurysmal zone. (d) and (e) represent the postoperative ^{131}Cs scintigrams. The cardiac volume is considerably reduced; a smaller area of decreased ^{131}Cs uptake still persists. The left ventricular cavity has resumed a normal aspect on the ^{113m}In picture (f).*
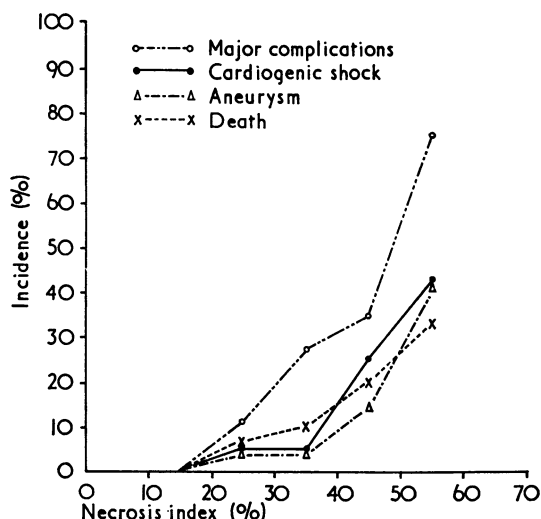
FIG. 6 *Correlation between the index of necrosis and the incidence of major complications.* Δ *development of parietal aneurysm;* ● *development of cardiogenic shock;* × *death;* ○ *presence of at least one of the three complications listed above.*

branch block, with left axis deviation; 4 showed left anterior hemiblock, which in 2 was combined with right bundle-branch block; 7, without fulfilling the specific criteria of left bundle-branch block, had severe intraventricular conduction disturbances with a QRS duration longer than 120 ms. Three disclosed signs of left ventricular hypertrophy and 3 only showed subepicardial ischaemia of the lateral wall. In the last case, the electrocardiogram, recorded 4 years after the acute episode of coronary occlusion, had recovered a normal configuration.

With a view to providing a semiquantitative evaluation of the extent of necrosis, the surface of the cold area as well as the total surface of the left ventricle were measured by planimetry in both the anteroposterior and left anterior oblique projections. The surface of the cold area was expressed as a percentage of the total left ventricular surface in the same projection. The mean value of the two percentages (anteroposterior and left anterior oblique projections) thus obtained was used empirically as an *index of necrosis*. In order to check its reproducibility, this index was measured on 32 successive patients by 3 different observers. A variance analysis revealed no significant difference between the 3 groups of measurements, the average values of the index of necrosis obtained by each observer being 33.1, 33.9, and 32.5 per cent, respectively. The coefficient of concordance of Kendall was also extremely satisfactory ($W = 0.93$).

The value of this index of necrosis was correlated with the electrocardiographic findings and with the clinical features. Fig. 5 correlates the value of the index of necrosis with the number of significant Q waves ($\geqslant 0.03$ s) depicted in leads I, aVL, V2, V3, V4, V5, or V6 of the standard electrocardiogram. It was readily apparent that the index of necrosis showed a tendency to increase as the number of pathological Q waves increased. A variance analysis carried out after submitting the index of necrosis to an arc $\sqrt{\sin x}$ transformation confirmed this assumption (Table). However, there were several individual exceptions where the scintigram displayed a large anterior defect while the corresponding electrocardiogram showed only very few pathological Q waves and vice versa. In several of these instances, the discrepancy could be accounted for by the presence of severe intraventricular conduction disturbances.

Fig. 6 indicates that the incidence of major clinical complications observed during the acute episode of myocardial infarction increased with the index of necrosis. It is interesting to note that no major complication occurred among the 27 patients whose index of necrosis was below 20 per cent. In contrast, 9 of the 12 subjects with an index of necrosis greater than 50 per cent developed one or more major complications (death, cardiogenic shock, parietal aneurysm). The incidence of rhythm disturbances would also have been interesting to correlate with the index of necrosis, but the patients in this group were not all initially admitted in our hospital or monitored in a coronary care unit; the data in their files were sometimes considered insufficient to allow such an investigation.

Discussion

Any noninvasive technique which provides pictures of the heart where myocardial infarctions can actually be seen, located, and even measured no doubt gives promise of a fine future. This is the case for myocardial scintigraphy. However, though sometimes very spectacular, the pictures obtained by [131]Cs scintigraphy should only be interpreted after having discussed the sensitivity, specificity, and accuracy of the technique.

As long as insufficient anatomo-scintigraphic correlative evaluation has been completed, one has to judge the sensitivity of the technique from data obtained by scintigraphic studies of cardiac phantoms and of dog hearts with experimental myocardial infarction. Such investigations, carried out in this laboratory, have indicated that [131]Cs does not provide satisfactory demonstration of lesions located on the posterior aspect of the heart (only

50% of posterior lesions can be visualized or suspected). It is, on the other hand, an excellent myocardial imaging agent for anterior infarcts. None the less, even for anterior lesions, it has been shown that necrotic areas smaller than 20 mm in diameter may sometimes be overlooked (Burguet, 1975).

As regards the specificity of the technique, the only potential problem might arise from the presence of the left ventricular cavity. One can easily imagine, on a theoretical basis, that if the left ventricular cavity were sufficiently large and the left ventricular wall sufficiently thin, the former might appear on the myocardial scan as a central cold area. From studies of cardiac phantoms, it has been inferred that when the ventricular wall is of normal thickness and the background noise is about 50 per cent of the maximum cardiac signal, the ventricular cavity will only show when the mean smaller diameter of its ellipsoid frontal projection exceeds 4 cm (Burguet and Merchie, in the press). Such conditions may sometimes be met in clinical practice, for example in the presence of a dilated heart. However, the systematic performance of scintigrams in both the anteroposterior and left anterior oblique projections easily permits the differential diagnosis. A cold area related to a dilated left ventricular cavity consistently maintains a central location in both views. In contrast, a cold area caused by a myocardial infarct either takes an eccentric position or appears as an indentation of the outer boundary in at least one of the two projections.

The phantom and animal studies also yield some information regarding the accuracy of the method. They indicate that the size of a myocardial scar is always underestimated by ^{131}Cs scintigraphy. This is not only because of the movements of the heart, but principally because of the use of collimators of high sensitivity and, hence, only fair resolution. The degree of underestimation is of course dependent on the dimension, shape, and location of the lesion; it may reach up to 25 per cent in the case of middle-sized anterior scars (Burguet, 1975).

In spite of its limitations and inaccuracies, ^{131}Cs myocardial scintigraphy appears to be a useful tool in the diagnosis and assessment of anterior myocardial infarction. Three reasons justify this statement.

First of all, this technique may, at times, make up for deficiencies in the electrocardiogram. It is well known that the electrocardiogram sometimes remains normal in the presence of a well-documented myocardial infarct (Horan, Flowers, and Jones, 1971). The fact that conduction disturbances, even hemiblocks, may hamper the electrocardiographic recognition of a coronary occlusion has also been repeatedly stressed (Rosenbaum, Elizari, and Lazzari, 1970; Durrer, 1972; Altieri and Schaal, 1973). The present series indicates that ^{131}Cs scintigraphy has been helpful in solving the problem of patients having a suggestive clinical history but whose electrocardiogram failed to show any specific signs of myocardial necrosis.

Secondly, ^{131}Cs scintigraphy, completed by a ^{113m}In investigation, also provided, in some cases, conclusive evidence for the existence of a parietal aneurysm.

Finally, the major advantage of the technique is to provide an easy semiquantitative estimation of the size of an infarcted area. The prognosis of patients suffering from acute coronary occlusion is determined by several factors: the extent of the infarcted zone is undoubtedly one of the most significant (Hanarayan et al., 1970; Page et al., 1971; Sobel et al., 1972; Alonso et al., 1973). It has for example been reported that cardiogenic shock occurs only in patients who, at necropsy, have an infarcted volume in excess of 40 per cent of the total left ventricular volume, septum included (Page et al., 1971).

Two different, non-invasive methods for estimating the size of an infarct have been previously used. Selvester, Wagner, and Rubin (1972) proposed a method based on electrocardiographic and vectorcardiographic criteria. The limitations of electrocardiographic techniques themselves reduce the value of this method: local proximity effects, cancellation phenomenon, and conduction disturbances represent serious and well-recognized potential sources of error (Selvester et al., 1972). Serial determinations of plasma enzyme levels offer another approach to the problem (Hemker et al., 1972; Sobel et al., 1972). However, to obtain an accurate estimation, a complex mathematical analysis of the serial enzymes changes is required. The method, based on data obtained on a dog model, has still to be further validated in the human; though promising, it remains cumbersome.

In comparison with these two methods, and for anterior infarction, ^{131}Cs myocardial scintigraphy seems as accurate and reliable. The index of necrosis described in this paper is admittedly purely empirical and constitutes only a rough estimation of the infarct size. It has, however, the advantage of being easy to measure and very reproducible. It has been shown to correlate with the incidence of major complications and can, therefore, be used as a prognostic index. It also provides the clinician with a sounder basis to form his long-term prognosis.

One can anticipate, however, that because of some of its disadvantages, ^{131}Cs will probably be

abandoned in the future in favour of a more convenient myocardial imaging agent.

As already stated above, ^{131}Cs has a low energy emission and a long biological half-life; it is moreover retained much longer in skeletal muscles than in the myocardium itself. These characteristics interfere with performance of serial scintigrams during the first 20 days following a single injection of caesium.

More energetic radionuclides with shorter biological half-life (^{129}Cs, ^{201}Tl, ^{43}K) should, therefore, be more favourable; they could be used with a gamma camera, would allow performance of serial scintigrams during the acute period following a coronary occlusion and, possibly, permit the demonstration of myocardial infarcts located on the posterior aspect of the heart. Their high energy emission however might invalidate quantitation by visualizing the cardiac cavities even in the absence of any dilatation.

It is hoped that further investigations will lead to significant improvement in the general clinical usefulness of myocardial scintigraphy. The purpose of this report was to show that, even though the technique has only reached the first stages of its development, the results so far obtained are sufficiently promising to justify continued effort in this field.

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